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Lunar Prospector To The Moon!

The Lunar Prospector began its journey to the Moon at 9:28:44 PM local time on 6 January from Cape Canaveral Air Force Station (CCAFS). The Prospector mission marks the first NASA lunar mission with scientific objectives since the Apollo 17 manned exploration in December of 1972. The Galileo spacecraft, although not commissioned to explore the moon, conducted two lunar flybys, generating energy to proceed on its mission to explore Jupiter and its moons. The first flyby took place during December 1990. The second flyby during December 1992 generated 53 images of the Moon.

Prospector was launched aboard Lockheed Martin's Athena-2 booster rocket along with a Trans-Lunar-Injection (TLI) stage built by Thiokol. The mission included a four minute launch window to take advantage of the Earth-Moon alignment which enabled the most fuel-efficient lunar transfer orbit trajectory for the spacecraft. After a ground-based tracking radar malfunction delayed the scheduled Monday launch, repairs were made and the entire launch and lunar transfer mission got underway successfully Tuesday evening.

The Athena-2 rocket delivered the spacecraft and the TLI stage into a 100-nm Earth orbit. The TLI stage included a set of small thrusters used to spin-up the TLI stage and spacecraft assembly prior to ignition and injection into lunar transfer orbit. Spin-up and ignition of the TLI stage occurred immediately after separation from the Athena-2 booster. The TLI stage increased the spacecraft velocity by 7,000 miles per hour, starting the spacecraft on its four and a half day voyage to the moon. Once expended, the TLI stage separated from the spacecraft. All subsequent trajectory corrections, orbit insertion, orbit trim and stabilization maneuvers have been performed by the hydrazine thruster propulsion system onboard the Prospector spacecraft.

Lunar Prospector with the Trans-Lunar-Injection (TLI) Stage

The spacecraft bus (primary structure) is constructed of graphite-epoxy and is cylindrical in shape, measuring 1.4 meters in diameter and 1.22 meters in length. The instrumentation is mounted on three mechanical arms, or "booms" which are stowed inboard during boost and Earth orbit injection. The mission event time line included deployment of the instrumentation booms during day one of the trans-lunar flight. Before deploying the booms, the hydrazine thrusters were used to increase the spacecraft spin rate to 57 revolutions per minute. As the booms deployed, the spacecraft spin rate slowed to 9 rpms. Once the booms were fully deployed, the thrusters were used to increase the spin rate back up to the desired 12 rpms. After deployment, the instrumentation packages were powered-up and collection of calibration data was initiated.

The spacecraft incorporates six 22 Newton monopropellant hydrazine thrusters and three spherical hydrazine tanks. Two thrusters are mounted on the top of the cylindrical bus, two on the bottom, and two are mounted on the long axis of the bus (non-symmetrically, less than 180 degrees apart). Each of the six thrusters were used in various combinations to perform

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CPIA's Technical/ Bibliographic Inquiry Service

CPIA offers a variety of services to its subscribers, including responses to technical/bibliographic inquiries. Answers are usually provided within three working days, and take the form of telephoned, telefaxed, or written technical summaries. Customers are provided with copies of JANNAF papers, excerpts from technical reports, bibliographies of pertinent literature, names of recognized experts, propellant/ingredient data sheets, computer program tapes and instructions, and/or theoretical performance calculations. The CPIA staff responds to nearly 800 inquiries per year from over 180 customer organizations. CPIA invites inquiries via telephone, fax, or letter. For further information, please contact Bill Hufferd at (410) 992-7306, x.203 or e-mail: hufferd@jhu.edu. Subjects covered in recent inquiries include:

Technical Inquiries

- Ammonium picrate reactivity with metals.
- Swedish Bofors process for manufacturing TNT.
- Source for Polyglycidyl Nitrate (PGN).
- Composition of A-1A igniter.
- Class 1.1 propellant production and usage.
- Historical listing of ammonium perchlorate (AP) manufacturers and users.
- Density and Thermal Properties of JP-10, RJ-4, and PBXN-107.
- Synthesis of fluorodinitromethane (FDM).
- Long-term storage of ammonium perchlorate.
- Rhenium high temperature properties.

Bibliographic Inquiries

- Man-rating criteria for solid and liquid propulsion systems.
- Use of NDE/NDT for measurement of solid propellant mechanical and/ or chemical properties.
- Rheology of solid gun propellants.

Recent CPIA Publications

CPIA Pub. 657, *1997 JANNAF Propulsion Systems Hazards Subcommittee Meeting*, Vols. I and II, October 1997.

CPIA Pub. 661, *Fire and Explosion Hazards of Liquid Propellant and Related Materials - An Accident Overview*, October 1997.

CPIA Pub. 662, *1997 34th JANNAF Combustion Subcommittee Meeting*, Vols. I-IV, October 1997.

CPIA Pub. 663, *Integrated High Payoff Rocket Propulsion Technology Program (IHPRPT) Government Briefing for Industry*, October 1997.

CPIA Pub. 666, *1997 Airbreathing Propulsion Subcommittee Meeting*, Vols. I-IV, October 1997.

CPIA Pub. 667, *Technology Awareness Workshop on Active Combustion Control (ACC) in Propulsion Systems*, November 1997.

CPIA Pub. 668, *Safety and Hazards of CL-20 and Propellants and Explosives Based on CL-20*, November 1997.

LS98-01, *Electrothermal Gun Technology*, October 1997.

LS98-02, *Hydrazine Thrusters*, September 1997.

LS98-03, *Rocket Plume Base Heating Analysis*, September 1997.

CPTR 97-66, *Expendable Launch Vehicle Propulsion Systems*, December 1997.

The Chemical Propulsion Information Agency (CPIA), a DoD Information Analysis Center, is sponsored and administratively managed by the Defense Technical Information Center (DTIC). CPIA is responsible for the acquisition, compilation, analysis, and dissemination of information and data relevant to chemical, electric, and nuclear propulsion technology. In addition, CPIA provides technical and administrative support to the Joint Army-Navy-NASA-Air Force (JANNAF) Interagency Propulsion Committee. The purpose of JANNAF is to solve propulsion problems, effect coordination of technical programs, and promote an exchange of technical information in the areas of missile, space, and gun propulsion technology. A fee commensurate with CPIA products and services is charged to subscribers, who must meet security and need-to-know requirements.

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Meeting Preview!

The Nassau Bay Hilton & Marina in Houston,Texas is the site for the April 21-24, 1998 joint meeting of the JANNAF Propellant Development & Characterization Subcommittee (PDCS) and Safety Environmental Protection Subcommittee (SEPS). Over 85 technical presentations have been scheduled so far. Several joint sessions of interest to both propellant developers and safety/environmental protection specialists are planned, including sessions on new propellant and ingredient processing methods for pollution prevention; new propellant formulation developments towards reduced environmental impact; liquid propellant safety, characterization, and hazards; and safety characterization of solid propellant ingredients.

Additional PDCS sessions will cover solid propellant processing; characterization of ingredient particles and advanced propellants; propellant aging and other miscellaneous propellant characterization topics.

Additional S&EPS sessions will cover new rocket motor hardware and component technologies for pollution prevention; demilitarization, disposal, and recycling of propellants and munitions; treatment of liquid propellant wastes; toxic hazards and industrial hygiene/occupational safety aspects of propellants; and environmental impact and health issues associated with space launch vehicle exhaust emissions and launch range operations. The S&EPS will also hold focused panel sessions to address a JANNAF task to revise CPIA Publication 394 *Hazards of Chemical Rockets and Propellants* and also to examine other potential JANNAF activities related to launch range safety. For details on the meeting please call Sylvia Gomez-Knight, CPIA (410) 992-7303, x.213.

CPIA Home Page
http://www.jhu.edu/~cpia/
Go There!

The *Bulletin* Board

The following are various meetings and events. We welcome all such announcements, so that the propulsion community can be better served with timely information. See CPIA's Homepage "Calendar of Events" link (URL=http://www.jhu.edu/~cpia/).

Dates 1998	Topic	Sponsor	Location
3/16-20	JANNAF Structures and Mechanical Behavior Subcommittee, Non-Destructive Evaluation Subcommittee, Rocket Nozzle Technology Subcommittee Joint Meetings	CPIA	Salt Lake City, UT
3/17-20	Missiles 1998: Europe's Leading Missile Symposium	RUSI	London, UK
4/20-23	39th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference AIAA/ASME/AHS Adaptive Structures Forum	AIAA	Long Beach, CA
4/21-24	1998 JANNAF Propellant Development & Characterization and Safety & Environmental Protection Subcommittee Joint Meeting	NASA	Houston, TX
4/27-30	8th International Space Planes and Hypersonic Systems and Technologies Conference	AIAA	Norfolk, VA
5/4-6	Global Air & Space '98 Conference	AIAA	Arlington, VA
5/5-7	UXO Forum 1998	DDESB	Anaheim, CA
6/8-12	Hydrogen Peroxide Propulsion Workshop	EOARD*	Guildford, UK
6/22-26	International Workshop on Measurement of Thermophysical and Ballistic Properties of Energetic Materials	EOARD**	Milano, Italy
6/30-7/3	29th Annual ICT Conference: Energetic Materials - Production, Processing and Characterization	ICT	Karlsruhe, Germany
7/13-15	34th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit	AIAA	Cleveland, OH
7/15-17	1998 JANNAF Propulsion Meeting	CPIA	Cleveland, OH
7/27-31	24th International Pyrotechnic Seminar	IIT	Monterey, CA
8/18-20	28th DoD Explosives Safety Seminar	DDESB	Orlando, FL
8/30-9/4	11th Detonation Symposium	NIMIC	Aspen, CO
11/9-13	JANNAF Exhaust Plume Technology Subcommittee and SPIRITS Users Group Meeting	CPIA	Kennedy Space Center, FL

AIAA = American Institute of Aeronautics and Astronautics, (703) 264-7500
EOARD** = Aeronautical Sciences, +44 171-514-4299
EOARD* = Aerospace Structures and Materials +44 171-514-4318
CPIA = Chemical Propulsion Information Agency, (410) 992-7300, x.202
DDESB = Department of Defense Explosives Safety Board, (703) 325-1375
ICT = Fraunhofer-Institut fur Chemische Technologie, +49 - (0)721-4640 - 0
IITRI = IIT Research Institute, (630) 790-9526
JANNAF = Joint Army-Navy-NASA-Air Force; call CPIA at (410) 992-7300, x. 202
JHU/APL = Johns Hopkins University/Applied Physics Lab, (410) 792-5000
NASA = NASA Johnson Space Center, call CPIA at (410) 992-7300, x. 202
NIMIC = NATO Insensitive Munitions Information Center, (32)(2) 728.5416
RUSI = Royal United Services Institute, +44 171 252 2222

Lunar Prospector... *continued from page 1*

trajectory correction maneuvers during trans-lunar flight and to establish the desired lunar orbit. Each of the hydrazine tanks were initially loaded with approximately 56 kg of hydrazine and 0.5 kg of helium pressurant. The spacecraft carries enough hydrazine fuel to conduct the initial one-year mission and a possible two-year extended mission. If the extended mission is implemented, the spacecraft will lower itself to 50 km altitude for an unspecified duration, and then drop down to 10 km altitude for the duration of the mission. The total spacecraft weight, loaded with propellant, is 295 kg.

The spacecraft was required to make two trajectory correction maneuvers while in trans-lunar flight. The initial correction required a significant duration firing of two thrusters. The second correction required a very short duration burn. Additional thruster firings of short duration were required to properly orient the spacecraft for Lunar Orbit Insertion (LOI). The initial LOI burn required a significant duration firing to slow the spacecraft and establish a 12-hour elliptical orbit. A second burn was later performed to establish a three and a half hour circular orbit. A third, moderate burn placed the spacecraft into the desired two hour, circular polar orbit. One final thruster firing of very small magnitude was performed to shape the spacecraft's final polar orbit. Additional thruster firings are planned periodically (approximately one firing per month) to offset the effects of gravitational orbit decay and reestablish the desired orbit.

Onboard instrumentation includes Gamma Ray, Neutron, and Alpha Particle Spectrometers, an Electron Reflectrometer and a Magnetometer. The Gamma Ray Spectometer will detect any abundances of Aluminum, Calcium, Magnesium, Silicon, Oxygen, Iron or Titanium by detecting Gamma Rays emitted when atoms of the various elements are bombarded with solar wind or cosmic rays. The Neutron Spectrometer will detect any slow moving neutrons released from the lunar surface through interaction with solar winds, which will indicate the presence of frozen water. The Magnetometer and Electron Reflectometer will return data on the lunar surface magnetic field, most prominent at lava flow and meteor impact sites, to provide an understanding of the origin of lunar paleomagnetism. Additional instrumentation onboard will perform Doppler tracking of S-Band radio signals to characterize the spacecraft orbit and gather data on the lunar gravity field.

The one-year primary mission will include coverage of the entire lunar surface. The onboard instrumentation will collect data continuously. The spacecraft incorporates a low-gain omnidirectional antenna and a slotted, phased-array medium gain antenna and two S-Band transponders for spacecraft command and control and telemetry downlink of science data. Onboard solid state recorders store science data for up to 45 minutes while the spacecraft is shadowed from ground control stations. The record mode is activated just prior to Loss Of Signal (LOS) on each orbit. The stored data is transmitted to Earth ground stations at 3 kbps after Acquisition of Signal (AOS) as the spacecraft emerges from behind the Moon and line-of-site signal link is reestablished.

As of the writing of this article the mission is proceeding according to plan. All instrumentation is performing nominally and sufficient propellant remains to complete the primary and extended missions. GO PROSPECTOR!

Polybutadienes Dominate for 40 Years

Nearly all composite solid propellants manufactured today for domestic military and launch booster applications are based on one of three butadiene binder polymers: polybutadiene-acrylic acid-acrylonitrile (PBAN), carboxyl-terminated polybutadiene (CTPB), or hydroxyl-terminated polybutadiene (HTPB). Representative data for propellants based upon these polymers are found in the table below.

Liquid polybutadiene polymers were first investigated in the mid-1950's for the potential replacement of polysulfides. The terpolymer PBAN was developed in 1957 as an outgrowth of polybutadiene-acrylic acid (PBAA), the first hydrocarbon binder to be used in a rocket motor. The higher hydrogen content of liquid polybutadienes lowered the average molecular weight of motor combustion products while increasing flame temperature and enhancing the combustion of aluminized propellant formulations. The resulting increase in specific impulse made the polybutadiene propellant system an attractive candidate for the launch stage of the Minuteman missile.

Thiokol improved on the rather poor tear strength of PBAA propellant by adding about 10% of acrylonitrile, creating the terpolymer PBAN. Although Thiokol initially began the development of the M55 Minuteman 1st Stage with a PBAA propellant, the development of their "HB" series terpolymer led to the qualification and production of the PBAN propellant TP-H1011. The extensive experience base and solid background of PBAN characterization and aging data developed over the next decade was no doubt a factor in selecting a very similar propellant, TP-H1148, for the development of the Space Shuttle Solid Rocket Motor in the early 1970s.

REPRESENTATIVE CHARACTERISTICS OF POLYBUTADIENE-BASED COMPOSITE PROPELLANTS

	PBAN	CTPB	HTPB
I°_{sps}, lbf-sec/lbm	262	263	264
Flame temp., °F	5600°	5600°	5950°
Solids loading	84 - 86%	84 - 88%	88 - 90%
Aluminum content	16 - 17%	15 - 18%	18 - 20%
Cross linking agent	epoxides or aziridines	epoxides	isocyanates
Operating temp., °F	40° to 90°	-65° to 160°	-50° to 150°
Hazard Classification	1.3	1.3	1.3
Estimated Production to Date (million lb)	560	95	260

The United Technology Center (later the Chemical Systems Division), formed in 1959, engaged in company-funded research to develop PBAN propellants for use in large space boosters. This research led to successful 87-inch motor firings for NASA in 1960 and 1961. Subsequently, UT-CSD developed and produced the 5-segment solid rocket motors (SRMs) for Titan III, from which the 5½-segment Titan 34D and 7-segment Titan IV solid boosters evolved.

In 1962, Air Force funding was released to advance the state-of-the-art of large solid motors for potential application to DoD and NASA missions. Aerojet, UT-CSD, Thiokol, and the former Lockheed Propulsion Company (LPC) were all involved. LPC and Thiokol tested a number of 156-inch diameter motors while Aerojet successfully tested the largest solid motors ever built--three 260-inch motors containing nearly 1.7 million pounds of PBAN propellant each. Although the 156-inch and 260-inch designs never became operational, their technology contributed to the future development of other large launch boosters.

Over 500 million pounds of PBAN propellant have been produced since the late 1950s, more than any other type of composite propellant. This is due in large part to the Minuteman ICBM program, Titan launch boosters, and continuing production of the Space Shuttle Reusable Solid Rocket Motor (RSRM) which accounts for about half of all production to date. Substantial production of PBAN will continue for at least the next 10 years, although this will be largely limited to procurement of the RSRM and the Minuteman Propulsion Replacement Program (PRP). American Synthetic Rubber Corporation of Louisville, Kentucky has produced production quantities of the HB terpolymer for propellant applications for nearly 40 years.

The initial development of carboxyl-terminated polybutadiene polymers for rocket applications also occurred in the late 1950s. Aerojet developed the well-known CTPB propellant ANB-3066 for the Minuteman II/III 2nd Stage and Minuteman III 3rd Stage. By the 1970s, CTPBs made their way into tactical systems such as Sidewinder, Phoenix, AIM-7 Sparrow, Standard Missile, and Stinger, and into Thiokol's commercial Castor IIA and early Star® series motors. With over 50 million pounds and counting, the Minuteman program has produced more CTPB propellant than all other systems combined.

From the 1970s into the 1980s, most of the CTPB polymer market was shared by Phillips Petroleum Company's Butarez™ CTL and Thiokol's HC-434®. Consequent to the 1989 split of the nine-year marriage of Morton-Thiokol, the new Morton International assumed Thiokol's specialty chemicals business and now produces HC-434 and other former Thiokol® products. Phillips exited the market when a July 1996 fire caused major damage to its Butarez production facility in Borger, Texas.

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Polybutadienes Dominate... *continued from page 5*

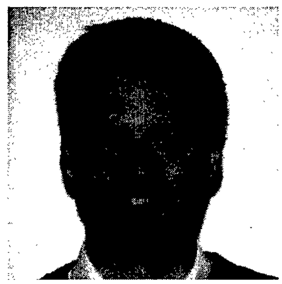
Although Aerojet reportedly investigated HTPB propellants in small motors as early as 1961, PBAN and CTPB remained the preferred formulations for solid composite rockets until the mid-1970's. With the desire for increased performance and adequate grain and binder mechanical properties over a wide temperature range, HTPBs were viewed as serious contenders for tactical systems by the early 1970s. Several companies and government propulsion laboratories were active in the development of higher performance propellants at that time.

HTPB propellant was first used and test flown in 1970 in Aerojet's Astrobee D meteorological sounding rocket. This was the result of a NASA-sponsored 1968 study of advanced propulsion concepts for small rockets. However, the transition of HTPBs into fielded systems was gradual. Eventually, systems such as Maverick, Stinger, Sidewinder and Castor IV upgraded from older composite propellants to the more desirable HTPB formulations. This biggest user of HTPB propellant has been the Army's Multiple Launch Rocket System (MLRS), with Atlantic Research Corporation producing over 130 million pounds for this program alone. Elf Atochem is the primary supplier of HTPB polymer, marketed under the trade names R-45M and R-45HT Poly B-D liquid resins. Atochem produces both aerospace and commercial grade material at the former Arco Chemical Company Channelview, Texas plant it acquired in the late 1980s.

Recently, the higher-energy HTPB has come into its own as a viable option for large boosters with the development and successful February 1997 maiden flight of the Titan IVB vehicle featuring the Solid Rocket Motor Upgrade (SRMU) manufactured by Alliant Techsystems (formerly Hercules Aerospace Company). The 3-segment SRMU succeeds CSD's 7-segment SRM which had been the Titan IV workhorse booster since 1989. The last Titan IVA launch with CSD boosters is scheduled for this year.

With production of the SRMU expected to conclude in 2001 and the Air Force's Evolved Expendable Launch Vehicle (EELV) adopting all-liquid propulsion designs, the application of HTPB propellants in the near future will rest primarily with small and medium launch vehicle boosters and tactical weapon systems. Substantial production is still foreseen for systems such as Extended Range MLRS, Standard Missile, AMRAAM, PAC-3, and AIM-9X Sidewinder. With a very active commercial satellite market, solid propellant launch boosters such as the Delta II/III GEM, Orbus 21, Castor® IVA/IVB, and Castor 120® will continue, however, to contribute to the HTPB propellant production base into the next decade.

This article previews the upcoming CPIA Technology Review, "Assessment of Polybutadiene-based Propellant Production and Usage in the United States - CPTR 98-67," authored by Thomas L. Moore, CPIA technical specialist in solid propulsion technology. Tom can be reached at (410) 992-9951 x.207.



Tom Moore

JANNAF Executive Committee Membership Changes

Changes in the JANNAF Executive Committee (EC) membership occurred at the December EC meeting. Mr. Lee Jones, of the NASA Marshall Space Flight Center stepped down as Chairman of the EC upon his retirement from NASA. Mr. Ned Hannum of the NASA Lewis Research Center will finish out Lee's term of office as EC Chairman, and Mr. Mark Stucker of the NASA Marshall Space Flight Center becomes the second NASA representative on the JANNAF EC. Other changes involved the replacement of Dr. E. Thomas Curran of the Air Force Research Laboratory Propulsion Directorate, Dayton, Ohio, by Mr. Parker Buckley, also of the AFRL Propulsion Directorate.

The JANNAF Executive Committee consists of eight regular members, two from each of the JANNAF agencies, with alternate members being designated as required to facilitate participation of the agencies in the JANNAF activities. Each member is a full-time employee of the Federal Government. The tenure of office of the members is the prerogative of the agency concerned, and is reviewed by each agency annually. The chairmanship is rotated among the agencies on a biennial basis. Designated representatives of the Deputy Director of Defense for Research and Engineering (DDR&E) and the NASA Headquarters are ex-officio members

The JANNAF EC is the governing body of the JANNAF Interagency Propulsion Committee. It is responsible for the establishment, modification, and dissolution of subcommittees; the monitoring of the activities of the subcommittees; and the promulgation of guidelines for their operation. Ad hoc committees are established for the purpose of coordinating and exchanging information on Government-funded RDT&E propulsion programs and for identifying and recommending special subjects of interest to the Executive Committee.

New Version of SPF-III Ready For Distribution

The latest version of the Standardized Plume Flowfield Model (SPF-III, version 4.0), developed by Propulsion Science and Technology, Inc. (PST) to calculate rocket plume flowfields in the altitude range from 0 to 70 km, has been delivered to the Chemical Propulsion Information Agency for distribution to the plume community. The development of this version, which was sponsored by BMDO, AFRL/PRSA, AEDC, MICOM and NAIC (via Ball Aerospace), was prompted by the need to improve the operation and reliability of the currently delivered version (version 3.5), especially when utilizing the base/separated region module. It has been demonstrated that accounting for plume/after body interactions provides more accurate IR signature predictions than those which use SPF flowfields employing the "flying plume" assumption. However, the base/separated region calculations had a number of limitations that needed to be corrected and a number of operational reliability issues that needed to be fixed. Below is a summary of all the upgrades that comprise version 4.0.

Plume Flowfield Calculations

- Revised coupling of core and shock layer computational domains for improved solution stability
- Corrected variable species term in SPLITP viscous characteristics expression
- Corrected several errors in SPLITP particle calculation
- Implemented step size cutback in farfield to eliminate instabilities for particles near equilibrium
- Corrected thermodynamic calculation for particles other than Al_2O_3 in farfield mixing calculation
- Upgraded Optrock Planck-averaged emissivity curve fits
- Corrected errors in chemical kinetics reaction types 3, 5 and 10
- Step sizes automatically revised when implementing Solomon smoothing
- Default carbon oxidation reaction changed to C(s) + OH CO + H
- Added functional form of Arrehnius expression - $A(R_p)$ for carbon oxidation reaction
- Incorporated particle supercooling
- Implemented revised k turbulence model compressibility correction

Base/Separated Region Calculations

- Incorporated 1-D chemical kinetics calculation
- Incorporated variable species and core chemistry in jet calculation
- Particle groups mapped and gridded independently
- Multiple particle types treated (Al_2O_3, ZrO_2, BeO, C(s), ZrC)
- Planck-averaged particle emissivities obtained from Optrock/Optpure libraries
- Revised coupling of jet and external computational domains for improved accuracy and flexibility
- Carbon oxidation computed
- Revised treatment of detached recompression shock
- Revised generation of viscous profile downstream of base triple point

Body Flowfield Calculations

- Incorporated error checking at body junctures
- Incorporated step size criterion which is responsive to local body geometry

General

- Incorporated double precision compilation option
- Improved Input/Output formats
- Incorporated interfaces to SIRRM-II, SIRRM-III and SPURC
- Incorporated interface to PARCS radar cross section code and PRFIC radar attenuation code

In order to obtain SPF-III, version 4.0, contact Dorothy Becker at CPIA, (410) 992-7302, x.204.

Call For Papers!

November 16-19, 1998
Insensitive Munitions and Energetic Materials Symposium

Sponsored by the National Defense Industrial Association (NDIA) and NATO Insensitive Munitions Information Center (NIMIC).

March 27, 1998 -- Deadline For Abstracts.

June 1, 1998 -- Authors Notified.

August 3, 1998 -- Program Agenda Released.

October 26, 1998 -- Papers Due To Kenneth Graham.

Please contact Kenneth J. Graham for abstract information (703) 754-5466 email: kgraham@arc-ag.com
For meeting requirements please contact (703) 522-1820. Refer to Meeting reference # 956.

Meeting Peeks!

AIAA Continues Solid Rocket Motor Lecture Series

The American Institute of Aeronautics and Astronautics Solid Rocket Technical Committee continued its tradition by holding a lecture series, this time on "Solid Rocket Motor Test and Test Techniques." The series was held January 14, and in conjunction with AIAA's 1998 Aerospace Sciences Meeting in Reno, Nevada. The objective of the lecture series was to provide an informative overview of the state-of-the-art techniques used to test solid rocket motors and component subsystems. The lectures, presented by nationally and internationally recognized experts, reviewed the interaction of customer requirements with sea level testing, simulated flight testing, flight testing, component testing and advanced measurement techniques. Presentations sought to describe the relevance of the methods to solid rocket testing, to provide a detailed description of the test methods, and to project future prospects where appropriate. A common theme throughout all the presentations was the concern for high quality data and lower test costs. The lecture series was organized and chaired by Dr. Rob McAmis (Sverdrup Technology Inc/AEDC). The lecture series is briefly outlined below, but a complete write up can be found on the CPIA Homepage in the Meeting Review section.

System and subsystem operational requirements lead to the definition of test requirements. **Lt. Col. Bill Taggart** (US Air Force, OO-ALC/LMP, Hill AFB) initiated the lecture by defining the source of customer requirements for solid propulsion system, subsystem and component testing.

Mr. Wayne Kallomaa (USAF) presented his views of sea level testing, covering what constitutes an ambient solid rocket test stand, the options available to help customers meet their test objectives and the issues which hinder the industry.

Mr. Randy Quinn (Sverdrup Technology Inc, AEDC) reviewed requirements for simulated altitude testing of solid rocket systems and surveyed the various ground test facility operational schemes.

Mr. Wayne Oden (Raytheon) described the testing strategy for assessing aerodynamic, kinematic propulsion system and guidance system performance of tactical missiles.

Mr. Ronald Fry (JHU/CPIA) described the importance of solid propellant burning rate characteristics to ballistic analysis and summarized the techniques used in the industry to measure and calculate burning rate. He highlighted how the complex burning behavior of energetic material contributes uncertainty to measuring burning rate accurately.

Mr. Phil Graham (ARC) discussed the need for characterizing the non-linear viscoelastic behavior of solid propellants.

Dr. Bob Brown (Consultant) talked about the need to instrument motors to measure their combustion stability behavior.

Mr. Hugh Reynolds (P&W/CSD) described test requirements and methods for assessing filament-wound insulated motor case strength.

Mr. R. Bruce Runyan (Sverdrup Technology Inc/AEDC) presented a lecture on techniques required for successfully measuring thrust of solid rocket motors.

Mr. D. Jon Rogerson (NAWC/China Lake) and **Mr. Jean Thepenier** (SNPE) each presented the application of real-time radiography (RTR) to assessing nominal performance, burnback behavior and solid propellant flaw behavior of SRMs.

Mr. Frank Cauty (ONERA) described the application of ultrasonic methods to assessing propellant grain surface regression and insulator behavior as functions of time and space.

Mr. George Wilcher (Sverdrup Technology Inc/AEDC) closed the day by reviewing the application of calibrated radiometric measurement systems to assess plume spectroscopy, radiative heating, thermal mapping, combustion gas emission/absorption, gas species identification and afterburning.

Copies of AIAA's lecture series on "Solid Rocket Motor Test and Test Techniques" can be ordered for $30 each from Dr. Rob McAmis (AEDC) at (931) 454-4951 or e-mail: mcamis@hap.arnold.af.mil.

Please *Go Home* to CPIA's Meeting Review Section (http://www.jhu.edu/~cpia/)

People in Propulsion

In Memoriam

Bo Stokes

Benjamin (Bo) Stokes, who died from injuries sustained in a car accident in December was a staff officer with NIMIC for five years, during which time he organized a number of Insensitive Munition (IM)-related workshops and prepared the associated workshop reports, particularly in the area of cook-off. As a NIMIC staff member from the US, he stayed abreast of developing IM technology in that country and interacted with his US co-workers in government, defense industries and universities to exchange technical information and to respond to questions related to IM subjects.

Mr. Stokes came to NIMIC following 27 years of experience in a US defense industry (Thiokol, Huntsville Division), where over that period of time, he performed solid rocket motor design and analysis studies on most of the US tactical rocket motors, interceptor motors, intermediate-size boosters and space motors that were designed, demonstrated and/or manufactured by his company. He has published (primarily in the JANNAF proceedings) over 20 technical papers on propulsion topics and has authored over 20 major technical final reports on Department of Defense contracted programs. He received his formal training first as an undergraduate in mechanical engineering at GeorgiaTech and later, after a diversion as a weather forecasting officer in the United States Air Force for three years, he attained a master's degree from MIT while he worked as a research assistant on solid propellant throttling devices.

Those of us here at CPIA who had the pleasure of knowing and working with Bo will remember him fondly.

Lee Meyer Retires

Lee Meyer retired on January 3rd 1998 from the Air Force Research Lab's Propulsion Directorate at Edwards AFB California.

He began his government service in 1967 after serving for four years as an Air Force officer. His service to the nation's defense spanned nearly thirty-five years.

Lee retired as the Associate Director of the lab's Propulsion Directorate and was responsible for the activities of more than 250 government and military researchers and support staff. These personnel were supplemented by nearly 250 support contractors in addition to base personnel who provided fundamental services.

His technical leadership has provided innovative improvements to rocket propulsion technologies ranging from tactical air launched missiles to ballistic missiles and space systems propulsion. He directed the concept definition of the Small Intercontinental Ballistic Missile and was the Director of Technology for the Advanced Launch System. That system and it's innovations are seen today in many aspects of the Department of Defense's Evolved Expendable Launch Vehicle program. Reagan's "Star Wars" program envisioned a space-based interceptor for defense against enemy missiles. Meyer directed the development of the Strategic Defense Initiative's, now known as Ballistic Missile Defense Organization, kinetic energy weapon propulsion system. The weapon uses either liquid or solid propulsion to steer itself into an impact path with an enemy missile. The technology is now being applied to a concept called Theater Missile Defense.

Most recently in addition to his lab management activities, he brought his expertise and leadership to instigating a national program involving the nation's rocket industry, NASA, and all services of the Department Of Defense. Called Integrated High Payoff Rocket Propulsion Technology or IHPRPT, it identified technology areas that will provide a doubling of rocket propulsion technology capabilities in a fifteen year period.

This same expertise led to the refurbishment of the historic Test Stand 1A for use by Boeing-Rocketdyne's large liquid rocket engine program scheduled to begin this spring.

There are two things besides his family that are near and dear to him. One is Texas A&M, his alma mater, and the other is the area of tactical missile development. Lee Meyer is well known in the world of tactical missile propulsion development, especially SRAM, AMRAAM, AIM-9P, AIM-9L, Shrike, Sparrow, and the Anti-Satellite Technology (ASAT) system.

Meyer has seen many changes in the lab facility at Edwards AFB. In his early career, it was known as the Air Force Rocket

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Lee Meyer Retires *continued from page 9*

Propulsion Laboratory. In 1987, the facility was renamed to reflect an expanded role in Air Force space research and development. The Astronautics Lab was consolidated in 1990 into the Phillips Laboratory, named in honor of General Sam Phillips who had launched the first experimental Minuteman I ballistic missiles out of silos at the Edwards facility. The facility became known as the propulsion directorate of the lab. Further consolidation by the Air Force formulated the Air Force Research Lab in 1997 and joined all propulsion research, rocket and airbreathing, together into a nation-wide propulsion directorate.

Meyer has seen the development and evolution of the nation's rocket propulsion capability at the lab. Nearly every rocket, launch vehicle or space propulsion system uses technology developed or tested at the lab. It has also set the stage for the future with advanced propulsion concepts like laser propulsion, electric propulsion, and solar propulsion.

Lee Meyer resides in Lancaster with his wife, Mary, a schoolteacher, and they are the parents of two sons and a daughter.

Lee Meyer

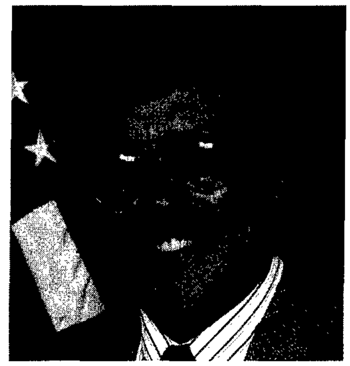
Rodgers Replaces Meyer

Dr. Stephen L. Rodgers is the Acting Associate Director of the Air Force Research Laboratory's Propulsion Directorate facilities located at Edwards AFB California. He replaces Mr. Lee Meyer, who retired in early January 1998.

Dr. Rodgers started his career at the facility in 1983 as a research scientist in the lab's Basic Chemistry Research Section. His initial work was devoted to solid rocket fuel ingredient research.

Dr. Rodgers has been appointed to positions of increasing responsibility during his lab career. Most recently, he created and directed the Propulsion Sciences and Advanced Concepts Division of the lab's Propulsion Directorate. His division combined the efforts of researchers located at the Edwards facilities working on rocket propellants, aerophysics, and propulsion materials with the efforts of counterpart facilities and researchers located at Wright-Patterson AFB, who work on aircraft.

He initiated the High Energy Density Matter (HEDM) project in 1984 and as a senior research scientist, has led the investigation into rocket fuels and oxidizers that have the potential to surpass present day capabilities. The HEDM research area is considered a Department of Defense Critical Technology fuels, lubricants, hypersonic technologies, and combustion. The division also includes a unique aerospace systems analysis group based at both locations.



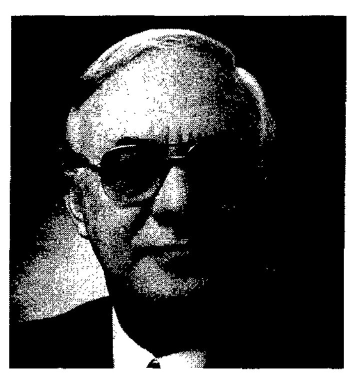
Stephen L. Rodgers

In addition to his current Division responsibilities, Dr. Rodgers now leads the rocket propulsion research efforts of 250 government and military researchers and support staff. These personnel are supplemented by an additional 250 on-site support contractors.

For more information contact Ranney Adams, Air Force Research Laboratory - Public Affairs, Edwards AFB CA 805-275-5465, or e-mail: ranney_adams@ple.af.mil.

Congratulations!

Mr. Ned P. Hannum was recently selected as the Chief of the Turbomachinery and Propulsion Systems Division at the NASA Lewis Research Center. The division is part of the Research and Technology Directorate and is responsible for providing research and technology for both airbreathing and space propulsion systems in connection with the Lewis Center of Excellence in Turbomachinery. Prior to this assignment, Mr. Hannum was deputy chief of the Space Propulsion Technology Division. He has been at Lewis for over 35 years.



Ned P. Hannum

98 JPM Co-located with the 98 AIAA JPC

The Joint Army-Navy-NASA-Air Force (JANNAF) Propulsion Meeting (JPM) will hold its 1998 meeting in Cleveland, OH, co-located with the American Institute of Aeronautics and Astronautics (AIAA) Joint Propulsion Conference (JPC). The dates for the 98 AIAA JPC is Monday-Wednesday, July13-15, and the 98 JPM will follow on Wednesday-Friday, July 15-17. Information about the 1998 AIAA JPC may be obtained by calling AIAA directly at 1-800-639-2422.

Unclassified sessions of the JPM will be held at the Cleveland Marriott Downtown at Key Center in Cleveland, OH, and two classified sessions will be held at the Celebreeze Federal Building approximately three-blocks from the Marriott. Attendance at unclassified sessions is limited to U.S. citizens whose organizations are certified with the Defense Logistics Services Center to obtain export-controlled technical data; participation in classified sessions is restricted to U.S. citizens who possess a personal security clearance of at least confidential with a need-to-know in the areas of rocket, missile, space, or gun propulsion technology.

A complete preliminary session schedule will be published in the next issue of the *CPIA Bulletin*. As of this printing, 137 papers have been scheduled in 19 technical sessions. In addition, four specialist sessions entitled "Cyclodextrin Nitrate Propellants," Model Based Formulations," IHPRPT Propellant Ingredients and Formulations," and "Past, Present, and Future Propulsion for the Advanced Medium Range Air to Air Missile (AMRAAM)" will be held. Highlights of this year's meeting include a "Plenary Session" in which representatives from each of the services and NASA will present information on one of their most emphasized programs. The meeting will close on Friday with an "Industry Round Table" discussion where representatives from four major propulsion companies will be asked to address the question "What do you see the business opportunities in the propulsion area to be in the next 5 to 20 years?"

Updated information about the 1998 JPM can be found on CPIA's web site: http://www.jhu.edu/~cpia/ or by contacting Debra Eggleston at (410) 992-7300, x.202 or e-mail: dse@jhunix.hcf. jhu.edu.

CL-20 Workshop

A JANNAF workshop on the Safety and Hazards of CL-20 and Propellants and Explosives based on CL-20 was held at the Thiokol Conference Center, Ogden, Utah on 18-19 November 1997. The objectives of the workshop were 1) to discuss work that has been performed; 2) to identify what additional research and development is needed to understand and control the hazards associated with CL-20 and formulations based on CL-20; and 3) prioritize the needed research and development. The workshop brought together experts in a variety of disciplines, including those involved with research, development, design, test and evaluation, and acquisition, and a cross section of representation from the Services, DoE, industry and academia.

Presentations were given about: incidents at facilities and reasons to care; Synthesis, Scale-up, Characterization of CL-20 as a neat material; Production of CL-20 and the way we use CL-20 in propellants and explosives; Explosives, (Propellants both gun and missile,) based on CL-20.

Groups worked together to develop priority issues concerning CL-20 and its use in propellants and explosives with emphasis on safety and hazards. At a dinner presentation Dr. David Flanigan of Thiokol shared his experiences in formulating propellant and designing the propulsion system for the Hellfire missile system. Flanigan's presentation underscored that there are many trade-offs that must be considered in designing propulsion systems and that there is an associated high risk. A workshop report entitled "Safety & Hazards of CL-20 and Propellants and Explosives Based on CL-20," CPIA Pub 668 is available to qualified individuals. To obtain this document, contact Ms. Dorothy Becker of CPIA at (410) 992-7302, x.204 or email at dlbecker@jhunix.hcf.jhu.edu.

Taurus Flies Again

After nearly four years of upgrades, Orbital Sciences' Taurus® rocket, a ground-launched derivative of the air-launched Pegasus, returned to the skies with the successful launch and deployment of a Navy GEOSAT and two ORBCOMM satellites on 10 February from Vandenberg AFB. The four-stage solid propellant rocket consists of Pegasus 1st, 2nd, and 3rd Stages stacked on a Castor 120® booster. The Castor 120® is a commercial derivative of the Peacekeeper 1st Stage which was used in the first Taurus® launch in March 1994, when two DoD satellites were successfully placed into orbit.

CPIA Bulletin

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JANNAF MEETING CALENDAR

1998	Meeting	Type	Location	Abstract Deadline	Paper Deadline
Mar 16-20	Nondestructive Evaluation Subcommittee / Rocket Nozzle Technology Subcommittee / Structures & Mechanical Behavior Subcommittee Joint Meetings	Conference/ Workshops/ Specialist Sessions	Salt Lake City, UT	Past	Feb 27
Apr 21-24	Propellant Development & Characterization Subcommittee and Safety & Environmental Protection Subcommittee Joint Meetings	Conference	Houston, TX	Oct 17	Mar 30
Jul 15-17	1998 JANNAF Propulsion Meeting	Conference	Cleveland, OH	Sep 8	May 22
Nov 9-13	JANNAF Exhaust Plume Technology Subcommittee and SPIRITS Users Group Joint Meetings	Conference	Kennedy Space Center, FL	Jun 1	Oct 19
Dec 7-11	1998 JANNAF Combustion Subcommittee / Propulsion Systems Hazards Subcommittee / Airbreathing Propulsion Subcommittee Joint Meetings	Conference/ Workshops	Tucson, AZ	Jun 29	Nov 16

Attendance at JANNAF Conferences and Workshops is by invitation only.

MEETING CALENDAR SUBJECT TO CHANGE. FOR LATEST DETAILS, CONTACT CPIA AT (410) 992-7304.

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